

author. Mechanical tests indicate that the tubes are softer than the average of 32 samples of ordinary copper tube taken from consignments received from time to time. Nevertheless, on cutting them with a chisel they do not show particularly soft metal.

Some time ago experiments were conducted at Crewe with fluted copper tubes, Fig. 5, but it was found that the ridges inside the tube suffered abrasion, especially at the commencement of the ridges, just beyond the ferrule, which were rather quickly worn through; consequently the use of such tubes had to be abandoned. An ordinary copper tube which has suffered abrasion rather severely, as will be seen from the corrugated appearance of the inside surface of the tube, is illustrated in cross-section in Fig. 6.

In conclusion, a form of steel ferrule, introduced by the author at Crewe some time ago, may be mentioned. The ferrules, which are stamped from mild-steel sheet, are, in the fourth of the five operations of manufacture, forced into a die which forms 16 small ridges,  $\frac{1}{16}$  in. in width and about  $\frac{1}{64}$  in. in depth on the outside. These ferrules, having a taper of 1 in 80, in addition to the ridges, are found to hold better in the ends of the tubes, which are rolled with parallel sides, than the plain turned ferrules with a taper of 1 in 40. An elevation and an end-view of this improved ferrule are shown in Fig. 7.

### The Tehuantepec Route.

BY E. L. CORTHELL.

After 384 years—Cortez to Diaz—with projects without number and failures many, and with persistent efforts on the part of Mexico; after the expenditure of large sums of money, the end is in sight, for the railroad across the Isthmus of Tehuantepec, from ocean to ocean, will be ballasted complete by the end of this year. There will be a depth of 22 ft. through the Coatzacoalcos bar in the Gulf at the end of 1905, with 33 ft. to follow. The Salina Cruz harbor on the Pacific will be protected by its two breakwaters in the sea and the inner port be ready for business, and at that time lines of steamships will be operating from both ports to the coastwise ports of Mexico and the United States and to other countries. The works from sea to sea are being prosecuted with all the energy possible by one of the most energetic and experienced contracting firms of the present day—Messrs. Pearson & Sons, of London—who are also the contractors for the four East River tunnels of the Pennsylvania Road between New York City and Long Island.

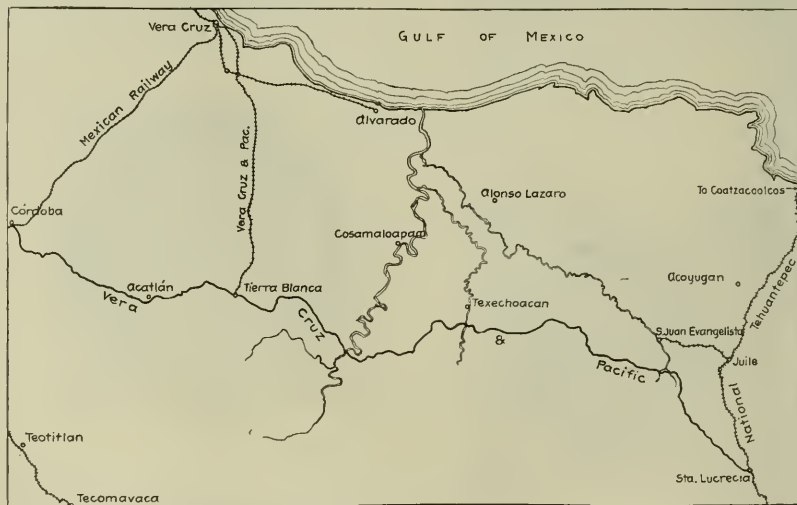
There are still—dating from November, 1903—over ten millions gold to expend on the two harbors and ports facilities. When the work is finally complete there will be open to the world's commerce a truly interoceanic route. The fact that the Mexican Government is a partner with Pearson & Sons in the construction and operation for 40 years of this route and that the Government by a "merger" with certain railroad companies now controls the operation of important systems extending from Laredo to Salina Cruz makes it important for the *Railroad Gazette* to briefly review the history of the project—dating back nearly 400 years, and to present advantages claimed for this route by President Diaz and his advisers. Their view, resolutely held, is that the Tehuantepec Route will be entirely completed and in full operation with its own lines of steamships eight years before the Panama Canal can possibly be opened to interoceanic traffic: that the Tehuantepec Route has immense geographic and naviga-

tion advantages over Panama and that it can easily draw to itself in the eight years all the traffic naturally tributary to it, and that, even after the opening of the Panama Canal, its excellent facilities for the prompt and economical handling of freight from ship to car and car to ship, will enable it to hold all it will have acquired; also that the ever-increasing volume of the world's commerce and of interoceanic traffic will enable the Tehuantepec Route to acquire its share of this increase, sufficient to make the great investments of the Government yield a fair return. It may be stated also that the Government of Mexico and its people have always believed it was their duty to the world to develop what they believe to be the natural and most advantageous route for the commerce of the world to pass between the oceans.

In 1520, as soon as Cortez, through the hospitality of Montezuma, was installed in the Aztec national palace, he inquired of the king if he had any charts of the coast. The king produced them and the eagle eye of Cortez at once lighted upon the mouth of the Coatzacoalcos river. Immediately a reconnoitering party was sent to explore it. The report was so favorable upon this landlocked harbor and the great river stretch-

brought forward and the Spanish Cortes authorized the opening of "a canal across the Isthmus of Tehuantepec in preference to Nicaragua and Panama." In 1824 a survey was made by Col. Orbegozo, appointed by the General Government. This was three years after Mexico became an independent republic. In 1842 President Santa Anna granted a citizen of Mexico, José de Garay, the right of way across the isthmus for a communication between the Atlantic and Pacific. This was about the time of the advent of railroads, and the grantee had the privilege of building a canal or to use "railroads and steam carriages." The survey for the route was made soon afterward by Gaetano Moro.

This concession was extended several times, and in 1848 Garay transferred his concession to an English company, and they in 1849 assigned it to Mr. Hargous, of New York. The Tehuantepec Railroad Company, of New Orleans, organized under the Garay concession, assigned to Hargous and began an exhaustive survey for a railroad in 1850, under the charge of Gen. J. G. Barnard. Topographical Engineer, assisted by Mr. J. J. Williams, C. E. Mr. Williams arranged and prepared the results of the survey in a published work of about 300 pages and a



Map Showing Vera Cruz & Pacific Railroad.

ing many miles into the interior that Cortez urged upon the Emperor, Charles V. of Spain, to make this the route to Cathay. Cortez was so sure that it would be an interoceanic route some day that he asked for and received the grant of an immense tract of land in the interior of the isthmus and was made Marquis of the Valley of Oaxaca. The route of the railroad of the present day passes through the lands of his descendants. They are called the Marquesanas—or estates of the Marquis. They embrace about 200,000 acres.

There is evidence that Cortez built a military road from the city of Tehuantepec on the Pacific to the headwaters of the Coatzacoalcos on the Atlantic, and that it was in use for a hundred years. A century later the Spanish viceroy was petitioned to declare Coatzacoalcos a port of entry and a great depot of commerce instead of the port and city of Vera Cruz.

The first real survey was made in 1774 by a civil engineer named Augustin Cramer by order of the Viceroy. He reported that, "It would not be a work of great difficulty, nor excessively costly to effect a communication between the two seas across this Isthmus." In 1814 another project for a canal was

book of maps. This work gave a "résumé of the geology, climate, local geography, productive industry, fauna and flora of that region." This very interesting work has formed the basis of all later studies. It was published in 1852. However, before work could be undertaken the Mexican Congress, in 1851, declared the concession granted in 1842 and amended in 1846 null and void on the ground that the acting-president had exceeded his powers.

During all the intervening five years there had been not only distrust of the people and Government of the United States, but for two years a war, leaving a fear of the overshadowing influence of the greater republic. They did not wish to have at Tehuantepec a repetition of what had just happened in Texas. This distrust was strengthened by some filibustering invasions of the border States of Mexico.

The distrust and the failure to conclude a treaty of neutrality over the Isthmus of Tehuantepec, which the United States Government would have been glad to celebrate, and the evident determination of the Mexican Government not to recognize the charter to Garay, which had come into the hands of United States citizens, led parties in the

latter country interested in Isthmus transit to apply to the Government of Granada for a concession. This was granted with a treaty between the two governments to build a railroad across the Isthmus of Panama, which was begun in 1850 and finished in 1855.

Had it not been for these conditions, no doubt the railroad would have been built at Tehuantepec at that time and none would have been built at Panama and no canal would have been built there; and Tehuantepec would now be the world's highway of commerce between the oceans, either by a railroad, as now; or by a canal, which Capt. Shufeldt declared entirely practicable after extended surveys, or by a ship railroad, as proposed by Capt. Eads.

After annulling the Garay grant the Mexican Congress in 1812 arranged for propositions on an international competition to open a route across the Isthmus. A company composed of Mexican and American citizens obtained the contract. Mr. A. G. Sloo was the moving spirit in this project, but nothing came of it, and it was annulled in 1857. In the same year a grant was made to the Louisiana Tehuantepec Company. This was twice extended, until in 1861 Napoleon III. instructed his minister in Mexico to secure the grant which this company had just forfeited, and this stood on the records until October 12, 1866, when Emperor Maximilian extended the time, but three days later—October 15—President Juarez,

the depth contemplated by the plans of the Government at Nicaragua at that date—60 ft. wide at bottom and 162 ft. at the top. The total length was to have been 144 miles and there were to have been 140 locks, all of very low lift, compared with modern lifts. The harbor conditions were reported to be very favorable on both sides of the Isthmus. As bearing on the entire subject of transit across the American Isthmus, the report of Admiral Shufeldt gives important testimony, and may be quoted here with advantage to the appreciation of the subject:

"I have, therefore, regarded canal communication through this hemisphere as American and local in its main object, incidental only as to the rest of the world. Viewed from this standpoint, a single glance at the map demonstrates not only the necessity of a canal, but its location. Each isthmus rises into importance as it lies nearer to the center of American political and commercial influence, and the intrinsic value of this eminently national work ought to be based upon the inverse ratio of the distance from that center. A canal through the Isthmus of Tehuantepec is an extension of the Mississippi River to the Pacific Ocean. It converts the Gulf of Mexico into an American lake. In time of war it closes that Gulf to all enemies. It is the only route which our Government can control. So to speak, it renders our own territory circumnavigable. It brings New Orleans 1,400 nau-

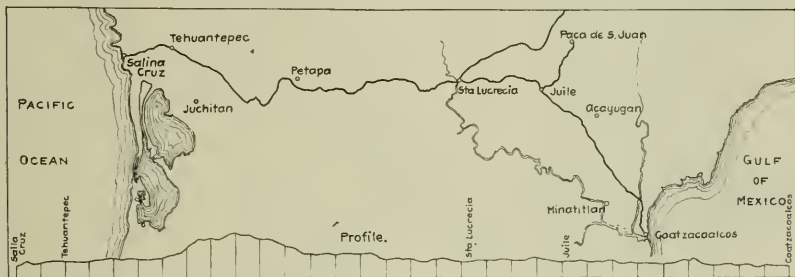
under this authorization the Government issued 5 per cent. gold bonds, the total issue being \$13,500,000, which were sold to a German syndicate of banks at 70 per cent. of their face value. A contract was signed with Edward McMurdo, of London, to build the road. He, however, died before he could enter actively upon the work. In 1892 the contract was abrogated, with about \$2,000,000 silver remaining from the proceeds of the issue of bonds.

The Government made a contract on February 27, 1892, with Messrs. Stanhope, Hampson and Corthell to spend this amount in an attempt to unite the rails. The amount was not sufficient and Mr. Stanhope himself afterward arranged for enough to accomplish this out of a special Government loan, and he expended on the work \$1,111,055. In 1898 the Government entered into a partnership contract with T. Pearson & Sons, of London. This was amended in 1902. This partnership, or "sociedad" was given the name of the "National Railroad Company of Tehuantepec." The contractors are the administrators or managers of the company's affairs.

The working capital is \$5,000,000. The profits and losses of the operation are to be divided between the partners. The contract will terminate in 1953 and it contemplates the construction of the harbors and ports on both oceans, the installation of port and terminal facilities and the entire rehabilitation of the railroad, cutting down steep grades, taking out objectionable curves, ballasting the road complete from end to end, establishing yards and sidings and equipping the road with sufficient rolling stock for a large interoceanic traffic. Special attention is being given to the terminals—a deep channel entrance to the natural protected harbor at the mouth of the Coatzacoalcas river and a protected harbor with an interior port at Salina Cruz on the Pacific. Those ports will be provided with the most modern appliances for handling cargo with the greatest possible despatch and economy. There will be 10 meters (32.8 ft.) of water at both terminals with wharves and docks sufficient for the largest ocean vessels.

By the courtesy of Sir Weetman D. Pearson and the Hon. Leandro Fernandez, Minister of Communications and Public Works of Mexico, we are enabled to present the plans of the works, including the map of the route and a map of its connections with the Mexican and Interoceanic railroads, and also the plans of the harbor, ports and terminal facilities. As will be seen by the topographic map, the ascent from the Gulf of Mexico is gradual, over slowly rising land, to the table land, where the summit is about 924 ft. above sea level. The descent to the Pacific plains is much more abrupt. The plains on the Atlantic slope are, however, undulating and are traversed by many lateral streams of considerable size, tributary to the Coatzacoalcas, which is the main drainage of an extensive country subject to an annual rainfall of about 100 inches. The irregularities required in the preliminary construction an undulating grade and considerable sharp curvature. The heavier grades were from  $1\frac{1}{4}$  to 2 per cent. and the maximum curvature about 9 degrees about 600 ft. radius. The work of the present contract consists largely in cutting down unnecessary grades and in improving the alignment. The whole length of the route is 290 kilometers (180 miles). The gage is the standard of the United States—4 ft., 8 $\frac{1}{4}$  inches.

The rail originally laid was 56 lbs. per yard. That required by the present contract is 80 lbs. The original rail is all being renewed. The bridges were mostly



Route and Profile of Tehuantepec Railroad.

not recognizing the authority of Maximilian, granted the right of way for a railroad and telegraph line to the "Tehuantepec Transit Company" and annulled the charter of 1857.

The headquarters of this last mentioned company was in New York City, but this charter also was later forfeited. In 1867 the President of Mexico gave a grant to Emilio de la Sere, an American citizen. A company was organized in Vermont by Act of the General Assembly of that State. Some amendments by the Mexican Government followed and in 1870 an additional right was granted this company to build a canal also. One of the earnest and indefatigable workers in this project was Simon Stevens, well known in New York as a persistent promoter of this project. He was President of the company. He published a book of 90 pages with maps and illustrations on the subject of Tehuantepec.

About this time the United States Government sent a party to the Isthmus in command of Capt. Shufeldt "to ascertain the practicability of a ship canal between the Atlantic and Pacific Oceans." The results were given in a quarto sized book with numerous illustrations and maps, 190 pages of text and 20 maps and profiles. The principal Civil Engineering assistant to Capt. Shufeldt was the late Prof. E. A. Fuertes, Dean of Engineering of Cornell University. The physical and hydraulic conditions were found to be favorable for the construction and operation of a canal 22 ft. deep—about

tical miles nearer to San Francisco than a canal via Darien."

After several extensions and many failures to raise the money, the grant to La Sere finally was forfeited by act of the Government on May 31, 1879. In the meantime Mr. Edward Learned, of New York City, obtained a concession in 1879 with a subsidy of \$7,500 per kilometer. This grant was terminated in 1882 for failure to complete the road in the time specified in the contract, only 35 kilometers having been finished. The Government settled with the company, taking over all its property on the Isthmus and paying \$125,000 in Mexican silver dollars and \$1,500,000 in United States gold. From this time on the Government itself undertook to build the road.

First it appointed a representative who was really an agent to buy the material and do the work on account of the Government. A contract was then made with this agent—Mr. Belfin Sanchez, a Mexican citizen—with a subsidy of \$25,000 per kilometer of road built, but the work did not progress well and the contract was abrogated on April 25, 1888. Most of the work under this contract was on the Pacific side, that under the Learned contract being on the Atlantic side. The Government paid \$562,910 as the value of the work done and material furnished, and \$170,225 as representing the contractor's profits.

The President had been previously authorized by Congress to build the road, and



wooden trestles and pile bridges, except over large rivers. Permanent structures, masonry or steel, are now being substituted for them. The entire line is being ballasted, sidings are being lengthened, yards laid down and the whole route put into shape for a heavy interoceanic traffic, and the rolling stock is being supplied to meet the requirement.

About 126 kilometers (78 miles) from the port of Coatzacoalcos the Vera Cruz & Pacific Railroad joins the Tehuantepec Railroad, at the station Sta. Lucretia. This is the terminus of the former line, as shown by the accompanying map. By the courtesy of the Minister of Communications we are able to show this Vera Cruz line and the other lines centering at Vera Cruz as well as the line to Cordoba on the Mexican Railway.

It is not probable that the line of Vera Cruz will have much of the Isthmian traffic, for the reason that from Salina Cruz on the Pacific to Vera Cruz the route is 200

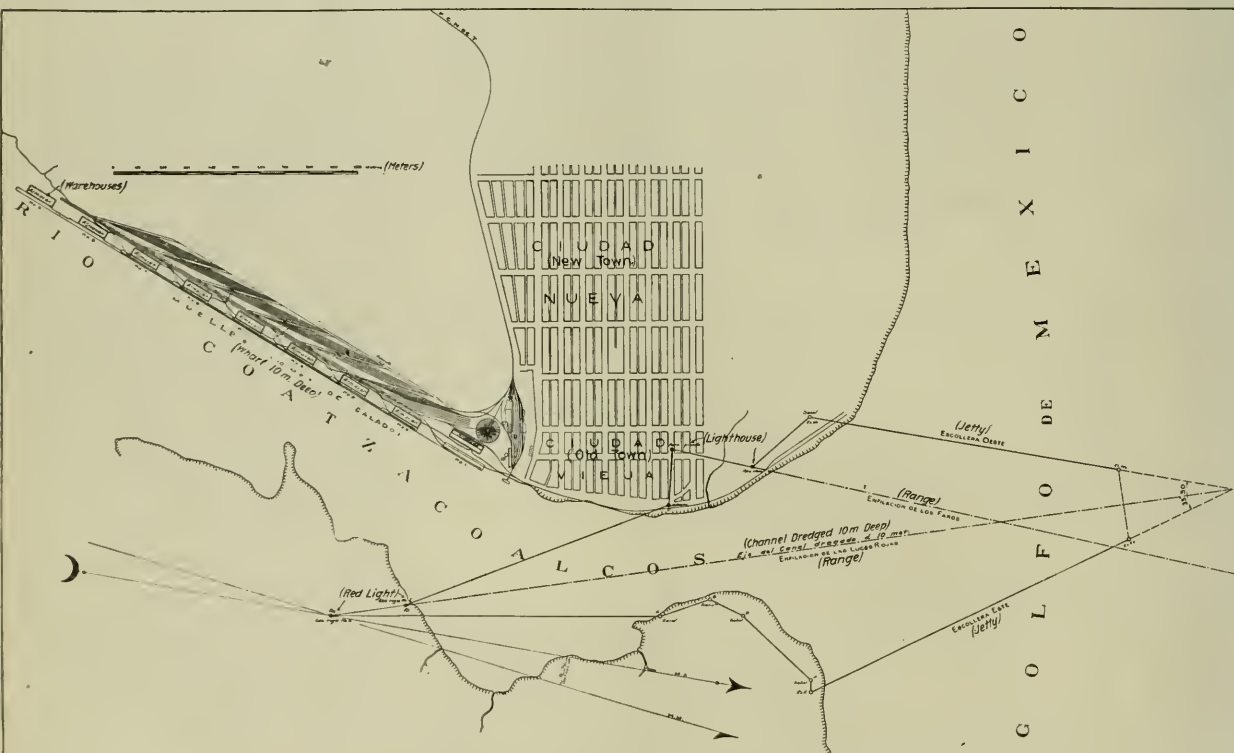
Buenos Aires. The fact that there is rail connection from the United States to the Tehuantepec Railroad is an important advantage to that railroad as an interoceanic route.

It is important in outlining the conditions of the Tehuantepec Isthmus route to know what has been planned, what has been done and what is yet to be done at the two terminals, for the value and real importance of this route as an interoceanic factor will depend upon the character of the terminal facilities.

At Coatzacoalcos the Government by a contract with Pearsons made a dredged channel through the sea bar at the mouth of the Coatzacoalcos river between the extensive deep basin inside and the deep water outside. The bar in its normal condition had about 14 ft. of water on its crest. The channel was deepened to 32.8 ft. and 328 ft. wide. A rise in the river, bringing down the usual amount of silt and debris shoaled the channel in 14 days to 14 ft. The plan then de-

tends over a mile and a quarter, with nine warehouses about 400 ft. long each, back of which is a railroad yard sufficient to handle the large number of cars required for an important traffic between rail and water. Four of the nine warehouses and the wharf in front are completed.

At Salina Cruz the conditions are entirely different. The waves of the Pacific beat upon the shore. There is no river to offer its basin for a harbor; only a long, curved shore line, with a promontory of porphyry rock 250 ft. high on the west, jutting boldly into the sea. This became naturally the base to which to tie a breakwater made out of the rock of the bluff. The stone blasted off became the foundation of a massive work formed of huge concrete blocks put in place by a powerful titan, which moves on the completed work. This dike is completed to within 100 meters (328 feet) of the sea end. The water deepens very rapidly, so that the dike will rest at the end in about 18 meters (59 feet) of water.



Port of Coatzacoalcos, Eastern Terminus of Tehuantepec Railroad.

kilometers (124 miles) longer than from Salina Cruz to Coatzacoalcos. There is, however, likely to be an important passenger traffic and Mexican freight traffic, via Vera Cruz, due to the fact that the Mexican Government has recently entered the railroad arena by arranging the "merger," previously referred to, of several systems in which it has lately obtained a controlling interest by purchase of a majority of stock. By those negotiations the Government has a majority ownership in an extensive system, reaching from the United States border to Salina Cruz, via the Mexican National to the City of Mexico; the Inter-oceanic, from the City of Mexico to Vera Cruz; the Vera Cruz & Pacific from Vera Cruz to Sta. Lucretia; and by its absolute ownership of the National Railroad of Tehuantepec from Sta. Lucretia to Salina Cruz. This is a long link in the proposed Inter-continental system from New York to

cided upon and now being carried out as rapidly as possible is to build two permanent, substantial jetties of stone and concrete blocks on the location shown on the plan.

As will be seen, those dikes converge from a width of about 3,445 ft. at the shores to 919 ft. at the sea ends, about 3,280 ft. from the western shore. The plan contemplates a permanent channel through the bar 656 ft. wide and 32.8 ft. deep at low tide. If the works do not produce and maintain this channel no doubt dredging will be resorted to to accomplish it. At this writing somewhat over one-third the length from shore of the west jetty has been built; no work has been undertaken on the east jetty as yet. The plan also shows the extensive and well designed railroad terminal at the port. A natural depth of over 30 ft. is within 100 ft. of the shore line for a distance of over a mile. The wharf frontage planned ex-

The east dike is built in the same manner and the two when completed leave an entrance about 656 ft. wide. The east jetty is built by carrying the materials along the shore from the promontory and depositing them by a second titan that operates on this work. About one-third the distance from the shore has been completed at this date. The plan clearly shows the details of the port itself. The ground where it is located is a low, flat marsh, which can be easily dredged. Across the rear of the protected area extends a line of wharfing with an opening for the passage of vessels into the interior basin. On this wharfing are six warehouses with railroad tracks on each side for handling goods between rail and ship. Back of an extensive interior basin is a row of piers and slips, which are to be built as the traffic requires it. This basin has a depth of 32.8 ft. and there is none less anywhere in the outer port in front

of the warehouses. It will be seen by a glance at this plan that an important business is expected.

The costs of the harbor, port and terminal facilities, not including the railroad tracks, yards, etc., are as follows:

Coatzacoalcas..	Total estimated approximate cost... \$8,959,786
	Completed to November, 1903..... 3,928,579
	Remain. to be done. \$5,031,207
Salina Cruz.....	Total cost..... \$24,983,615
	Completed to November, 1903..... 8,602,370
	Remain. to be done. \$16,381,045

These amounts are all in Mexican silver, the present rate of exchange being about 42 cents. As near as we can estimate the total amount in gold dollars which the Mexican Government will have expended, including interest paid out, from the beginning of its efforts to build the railroad under the Learned contract to the entire completion of the route ready for interoceanic traffic will be about \$33,000,000.

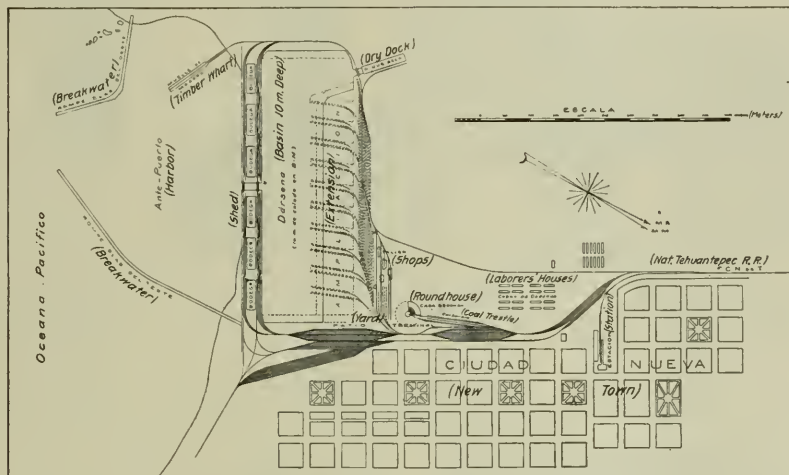
As stated by Admiral Shufeldt, the fact that Tehuantepec is nearer the "Axial line" of commerce of the world—Hongkong, Yokohama, San Francisco, New York, Liverpool—gives this route great advantages over Panama. An inspection of a globe will show

Algiers, opposite New Orleans. Each of the three under decks for freight has great side ports hermetically sealed on the voyage, but opened up as the steamer lightens up in discharging. These ports are high enough so that a gang of men can truck the freight out of the ship into the cars, which have their floors at the level of the wharf floor. When the upper deck has been unloaded, the ship lightens up out of the water sufficiently to allow the next set of side ports to be swung open, and so on to the third. Heavy freight—machinery, etc.—which cannot be readily trucked out is stored near the hatchways and lifted out by the ship's tackle and loaded on flat cars, which stand on a track immediately under the ship's side. The steamers are loaded from the cars in the same manner and in the same time. Ten hours will suffice to transfer a cargo of 5,000 tons from the steamer to a train of cars and start it on its journey over the Isthmus.

As to grain, instead of the long voyage of 16,552 miles around Cape Horn from San Francisco to Liverpool, the sailing ships that carry it could run into Tehuantepec, transfer their cargoes by the method above described, if the grain is in bags, as is usual on this route, or by elevators at the two terminals, if in bulk, and save 8,250

active cost of transportation over the two routes, this will depend in part upon the tolls and rates in each case, but as both routes are operated by governments we may assume that there will be competition and the rates scaled to secure all the business possible.

The extra cost of the four days to a steamer, say, \$2,000, plus the canal tolls, would make a 5,000-ton cargo cost about \$10,000 via Panama. No doubt the cost by Tehuantepec would be no greater and there would still be the saving in time of four days, which, to quick freight, is of great importance in this age of rapid transportation. Many estimates have been made of the tonnage to be expected over a trans-isthmian route. Some of these have been carefully worked out on a correct basis and some have been guessed at. Assuming 6,000,000 tons, which is about an average of the estimates, there is no doubt that, during the eight years when the completed and equipped Tehuantepec Route will be in operation before the Panama Canal will be ready to receive traffic, this route will draw to itself at least one-half of the tributary tonnage, and it is reasonable to expect that even after the Canal has opened it will hold all the tonnage acquired which is tributary to this route.



Salina Cruz, Western Terminus of the Railroad.

that the shortest ocean route from Panama to the East—Yokohama and Hongkong—must pass along our coast to at least off San Francisco. In fact, the shortest line—the great circle—drawn between Panama and Yokohama passes through the Gulf of Mexico at Corpus Christi, more than one hundred miles east of San Francisco and through the Aleutian Islands. We may assume that the average saving in distance by the Tehuantepec Route over Panama to all points on our Atlantic coast and Europe is about 1,250 miles. The ordinary freight steamer makes about 10 miles an hour, or, say, 250 miles per day, requiring five days longer via Panama, assuming the time of crossing the two isthmuses to be the same. It will take a steamer about one day to pass through the Panama Canal and the freight about two days to pass over Tehuantepec from ship to ship, leaving still four days to the advantage of Tehuantepec.

It is assumed that at Tehuantepec the methods of handling cargo are the best and the quickest now employed anywhere. If the steamers built for this route are designed like the Morgan line steamers running to New Orleans and Galveston from New York, they will be able to discharge or load 5,000 tons of freight on board cars or on board ship in 10 hours. This is done regularly at

miles, really 12,000 miles, for actual sailing distance is generally 50 per cent. greater than steaming distance.

This brings up another important matter which should not be lost sight of, viz.: the nautical advantages of Tehuantepec. It is safe to say that sailing vessels will never use the Panama Canal. They cannot reach it or get away from it. They always avoid the region of calms that prevail on both oceans opposite Panama. The opinion of Lieut. Maury still holds good. He summed up the nautical advantages as follows:

"Should nature by one of her convulsions rend the American Continent in twain and make a channel across the Isthmus of Panama or Darien as deep, as wide and as free as the straits of Dover, it would never become a thoroughfare for sailing vessels, saving the outward bound or those that could reach it by leading winds."

It is a mistake to assume that the sailing vessel is passing and soon to give way entirely to steamers. The sailing fleet of the world, while diminished in numbers, is still an important factor in ocean commerce, and as to the coastwise commerce of this country, it is still more important. Probably the coastwise tonnage in sail is twice that of steam, even figuring the steam ton as four times the sail ton. As to the rel-

#### Bending Moments in Rails.\*

Wheel effects of moving locomotives are resolved into negative and positive bending moments by the rail when depressed from its unloaded position in the trackman's surface to its loaded condition in the "general depression." From a continuous beam resting on numerous cross-ties, as flexible supports in the ballast, and the latter upon a compressible subgrade, the rail, by the progressive loading, is converted into a "constrained beam," strengthened and stiffened to carry and distribute the driving wheel loads and the tractive effort. The cross-ties are flexible supports depressed more directly under the wheels than in the wheel spacing, and do not control the span of the bending rail, as generally supposed.

The wheel spacing and the wheel loads, loading the rails at intervals of two or three cross-ties, become the more important factors in fixing the span of the bending rails. When the rail is well spliced and stiff, it may be strengthened and stiffened by parts of the load of the locomotive for carrying and distributing the loads, etc. This favorable action of the rail as a beam loaded in the "general depression" (unique in mechanics) is in part due to the flexible supports upon which it is depressed by the several wheels of the subdivided total load, each wheel load causing conjoint strains in the metal of the section, which assists to check deflections under adjacent wheels. The foundation is also favorably loaded and restricted in its movements.

A single pair of wheels in a long wheel spacing, independent of the conjoint action of other wheels on the rail, has a limited "general depression" confined to one specific deflection under the wheel. The looseness of the track not being reduced by preceding wheels, the positive bending moment is constrained only by the superstructure, instead of adjacent wheel loads.

In some stremmatograph† tests the total static load of the locomotive was 220,000 lbs., drawing a train of four cars, total weight of 430,000 lbs. In another test the total static load of the locomotive was 282,900 lbs., draw-

\*Extract from a paper by P. H. Dudley read at the Atlantic City meeting of the American Society for Testing Materials, June, 1904.

†The stremmatograph is an instrument devised by Dr. Dudley for measuring the deflections of rails under moving loads.